Digital Measurement of Head Shape Parameters at the Point-of-care

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Background: Up to 20-30% of newborns in the U.S. manifest deformational plagiocephaly and brachycephaly (DPB) which in most cases, can be effectively corrected by repositioning or physical therapy if detected before 4-6 months of age. The cranial parameters associated with DPB include the cranial index (CI), cranial vault asymmetry (CVA), and cranial vault asymmetry index (CVAI). Currently, there is no tool available to pediatricians or parents to quantitatively measure these indices at the point-of-care. With computer vision, smartphone technology can facilitate the early detection and monitoring of DPB. Such a tool can be used effectively in a telemedicine encounter, proving especially useful when patients cannot be seen in person due to circumstances like the COVID-19 pandemic.

Objective: To develop algorithms for measuring head shape parameters associated with DPB from photos taken at the point-of-care, e.g., at the pediatrician's office or at home.

Methods: Three-dimensional (3D) head scans of 100 infants (age range 3 to 20 months, 65 male, 35 female) were acquired using TechMed3D's BodyScan Scanner and MSoft . Ten infants had normal head shape and 90 had DPB. CI, CVAI, and CVA were estimated using image analysis algorithms from the top views of the head scans such as those in Fig. 1. A circular reference sticker of one-inch diameter was placed on the head in each view for calibration. A linear regression model was used for each parameter to improve the accuracy of our estimates. Leave-one-out-cross-validation was used to train and test the model, and the estimates were compared to the ground truth parameters obtained from digital 3D measurements via Bland-Altman analysis.

Results: The mean absolute error of our method was 1.78 ± 1.37 % for CI, 1.38 ± 1.30 % for CVAI, and 2.11 ± 2.06 mm for CVA. Spearman correlation coefficients of 0.91, 0.95, and 0.95 were observed for CI, CVAI, and CVA, respectively (see Fig. 2). Our CVA estimates (p-value < 0.001) are comparable to previously reported measurements by experienced anthropometrists using calipers (2.5 ± 2.2 mm; p-value = 0.004). Bland-Altman analysis results for all parameters are presented in Fig. 3.

Conclusion: Our digital method can measure head shape parameters from head photos with comparable accuracy to expert caliper measurements. This method can be deployed via a smartphone app to enable frequent infant cranial measurements at the point-of-care, and provide decision support tool for pediatricians and care givers.

Figures:

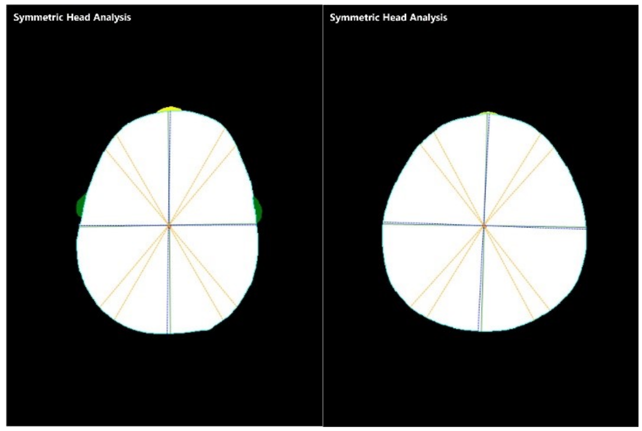

Figure 1: Top views of head scans with normal head shape (left) and brachycephaly (right) after semantic segmentation into head components. Blue lines are used to determine CI and the orange diagonals for CVA/CVAI.

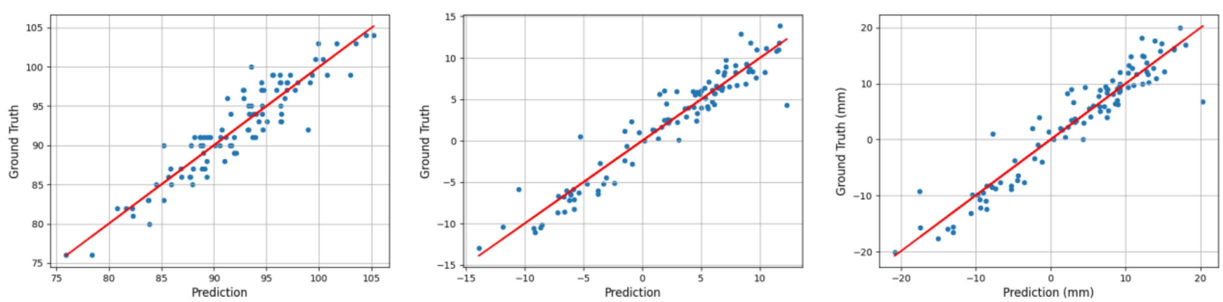

Figure 2: Correlation between ground truth and image-based predictions (DCVM) for: CI ($R^2 = 0.86$; $p < 0.001$), CVAI ($R^2 = 0.92$, $p < 0.001$), CVA ($R^2 = 0.91$, $p < 0.001$) *(left to right)*

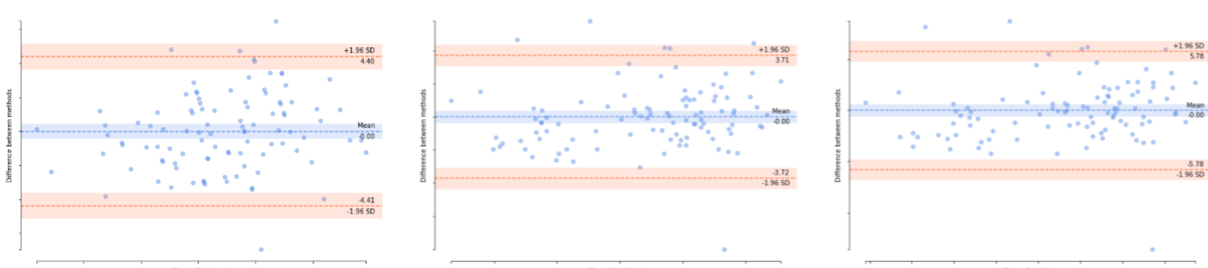

Figure 3: Bland-Altman comparison of ground truth and predicted measurements (DHCM) for: CI, CVAI, CVA (in mm) *(left to right)*